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Grid electrification challenges, photovoltaic electrification progress and energy sustainability in Lesotho

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ABSTRACT

Lesotho's energy profile is characterized by a predominance of traditional biomass energy to meet the energy needs of the rural households and a heavy dependence on imported petroleum for the modern economic sector needs. As a result, the country faces challenges related to unsustainable use of traditional forms of biomass and exposure to high and unstable oil import prices. There are relatively abundant renewable energy resources in the form of hydro, solar and wind. The average daily solar radiation in Lesotho varies between 4.5 and 6.5 kWh/m^2, with some areas in the South West averaging over 7 kWh/m^2/day. Under the UNDP/GEF-supported Lesotho Renewable Energy-Based Rural Electrification (LREBRE) Project, a total of 5000 solar home systems (SHS) will be installed by 2012. Since the start of the project, a total of 1537 SHS with a capacity of 65 W have been installed, and an estimated 500 SHS have also been independently installed as a result of the project's influence. This paper examines the role of PV technologies in the sustainable development process, with particular reference to UNDP/GEF-LREBRE Lesotho PV project, and the extent to which this project is impacting on the PV industry. The paper also analyses national grid electrification and energy provision in rural areas and shows that the problem of rural electrification could be tackled by conventional and non-conventional means.

Contents

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1. Introduction and background

Energy is central to sustainable development and poverty reduction efforts; its availability influences the lives of poor people and their ability to escape poverty. Without energy there can be little economic development and hardly any access to basic needs: clean water, refrigerated food, medicines, telephones, radios and televisions, let alone computers and the internet. Energy serves as an important contributor to socio-economic development when used for productive income generating activities. The majority of Lesotho's population, primarily living in rural areas, lacks some basic facilities because of insufficient access to energy. Lack of access to a reliable energy source is a major impediment to sustainable development. Though not specifically referred to in the targets of the Millennium Development Goals (MDGs), energy supply is a crucial requirement to achieve most of the MDGs [1–3]. Achieving every one of the following six goals requires the usage of energy:

1. *Halving extreme poverty*: energy for income generation.
2. *Halving the number of people living with hunger*: energy for agriculture and food processing and irrigation.
3. *Achieving universal education*: energy for lighting, communications and internet. Qualified teachers prefer schools with electricity supplies.
4. *Promoting gender equality*: reduce burden of firewood collection, cooking time, indoor air pollution and improve opportunities for education. Street lighting also improves women's safety.
5. *Reducing mortality/improving health*: reduce indoor air pollution, vaccinations require refrigeration; providing energy for use of ICT equipment contributes to combating spread of HIV/AIDS through propagation of information.
6. *Ensuring environment sustainability*: reduction in the use of firewood and reduce production of greenhouse gases.

Provision of modern energy services is in line with the strategic intervention pillars of the Poverty Reduction and Growth Strategy (PRGS) and Country Strategy Paper (CSP) for Lesotho (2008–12) [4], which are, in turn, derived from the Lesotho's Vision 2020 [5]. Modern energy services can also make a significant contribution to achieving the key commitments of the New Partnership for African Development (NEPAD) agenda [6]. The commitments include employment creation, infrastructure development, food security, rural development, poverty eradication, putting Africa on a sustainable growth and development path, and promoting the role of women in all activities. Although energy per se does not alleviate poverty, there is a strong link between development and the availability of electricity.

Global issues, such as climate change, economic downturn and volatile energy prices have exacerbated the problem of energy access in the country. However, the Lesotho Government is cognisant of the impact of lack of access to energy services on the economic and social development of the rural people. This realisation is amply demonstrated by the increased budget allocation for rural electrification projects. In the 2010/11 national budget the government allocated about US$6.5 million towards rural electrification projects, which is about 50% more than the previous financial year [7]. It is worth noting that the increase came at a time when budgetary cuts were being effected in all governments departments, a reflection of serious commitment by the government.

2. Present energy scenario

Lesotho's energy balance is dominated by biomass energy resources, with its associated environmental degradation in the form of deforestation and soil erosion, a phenomenon likely to continue until renewable energy technology becomes economically viable in the country. Energy comprises about 10% of Lesotho's gross domestic product, creating employment for about 0.1% of the population [8]. Energy consumption has grown at the rate of about 9.0% per annum, which has exceeded the GDP growth rate of 2.1% over the same period. The country's primary energy base consists of hydroelectricity, biomass, and petroleum products. The national energy consumption distribution by type is illustrated in Fig. 1 [9]. Most households generally use a combination of energy sources for cooking that can be categorised as traditional (such as dung, agricultural residues and fuel wood), intermediate (such as coal and kerosene) or modern (such as liquefied petroleum gas (LPG) and electricity). Electricity is mainly used for lighting and small appliances, rather than cooking, and represents a small share of total household consumption in energy terms.

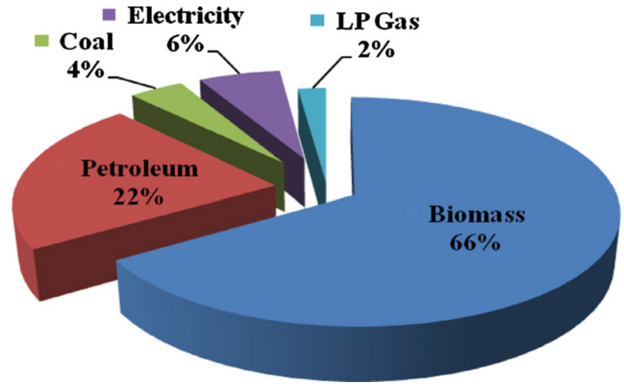

Fig. 1. National energy consumption in 2008.

The national energy use reveals a dichotomy between urban and rural households. Out of the total energy consumed in 2008, commercial energy (petroleum products, LPG, coal and electricity) accounted for about one-third, while the remaining share went to traditional fuel (mostly fuel-wood and other biomass). Fig. 1 gives a graphic illustration of this dichotomy in commercial and traditional energy consumption patterns in the country. Fig. 2 shows a distribution of traditional energy consumption in 2008. Traditional fuels contributed 95% of the rural energy consumption, with fuel wood being the most important source (40%), followed by shrubs (33%), animal dung (22%) and small amounts of crop residues (5%). Agricultural residues are mainly used to start and support wood combustion. In general, the rate of utilization of this energy source far exceeds the production level [10]. Rural areas are facing an acute shortage of wood as well

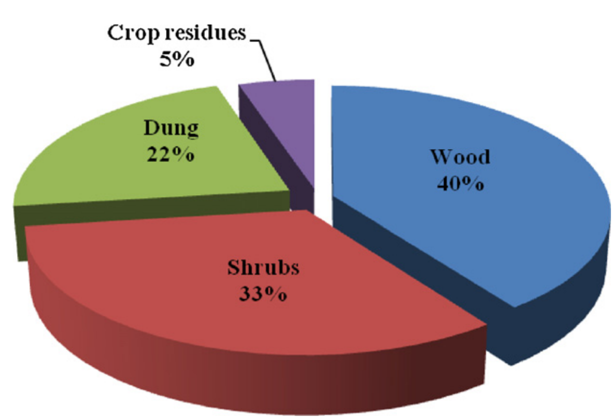

Fig. 2. National biomass fuels consumption in 2008.

as the associated land degradation of the already fragile environment.

2.1. Outlook for household energy use in rural areas

Improving electricity access to the rural communities of Lesotho continues to be a major challenge. Even though Lesotho is relatively a small country (30,355 km^2) with an estimated population of just over 2 million, two-thirds of the country is sparsely inhabited, comprised of rugged mountains and deep valleys with small, scattered villages on mountain sides. The remaining third consists of a lowland strip. Access to some communities is still only possible by foot or horse-back. The majority of the population (76%) lives in rural areas, but has strong links to urban centres in both Lesotho and neighbouring South Africa [11]. The houses are mostly single-room round huts with stone or mud and wattle walls and thatched roofs. The majority of these villages lack electricity and the probability of connecting them with grid electricity in the foreseeable future is very low. The daily average energy demands in these villages are generally low, varying between 0.5 and 1.5 kWh per household [11]. Where electricity is available, it is used mainly for lighting, TV and radio. Alternative energy options are limited to kerosene or candles for lighting, and biomass fuels (often burned in inefficient stoves) for cooking and space heating [12].

Rising prices of kerosene (currently US$1.15/l) and LPG (currently US$2.50/kg) mean that people living in these rural areas are being forced to pay more and more to light their homes and prepare their staple foods. Kerosene is not only increasingly expensive but also harmful to health and dangerous. It is also a fossil fuel that emits greenhouse gases that contribute to climate change. Estimates show that an average kerosene lamp spews out a tonne of CO_2 in less than 10 years [13]. Moreover, there are frequent reports of fire hazards (usually due to overturned candles, kerosene spill or LPG explosion) in which the poorest of the poor lose their possessions, suffer disfigurement or sometimes death [14]. Grid electricity, being a commercial form of energy, requires users to have a regular income. The income levels in rural areas are generally lower than in urban areas due to higher unemployment and underemployment levels.

Small diesel-engine generator sets of power range from 2 to 5 kV A are used by a limited number of villagers to cover power demands of their houses and by tradesman to power tools. Usually, due to high running costs, the operation of these generators is limited to night periods and light duties such as charging car batteries which are commonly used to run radios and TVs. The low voltage networks connecting these systems are mostly unprofessionally laid out, which makes them dangerous coupled with high power losses and frequent breakdowns. In addition, these generators are not sound-attenuated, causing noise pollution to the local environment. Other challenges include unavailability of skilled technicians in these areas, and inconsistent fuel supply. The price of diesel fuel in Lesotho is also high, usually more than US$1.25/l. Therefore, utilization of such generators does not provide a durable and effective long-term option in rural areas; since the poor effectively pay a much higher proportion of their income for the energy services than their urban counterparts. Further, they are more exposed to health hazards; and they also spend more time in collecting wood and other biomass fuels, which yields low energy output per kilo. Incidentally, much of the collection costs fall on women in those households. From the above articulated reasons it is apparent that the only cost effective option for rural areas is the use of stand-alone, household-sized renewable energy technologies such as solar PV, wind generators and small hydro plants.

3. Electricity supply and distribution

3.1. Overview of electricity sector

The electricity supply system in terms of grid-transmitted power is dominated by two wholly state-owned entities – the Lesotho Electricity Company (LEC), which is the monopoly transmitter, distributor and supplier of electricity, and the Lesotho Highlands Development Authority (LHDA), which is the main generator of electricity through the 'Muela hydropower station (MHP). Attempts to privatise LEC in 2001 were not successful, and it was then turned into a Company in 2002 that is wholly owned by Government. LEC's own combined generation from four small-hydro power stations is 3.25 MW. 'Muela hydropower plant has a maximum nominal generating capacity of 72 MW. However, in periods of national maximum demand, the generation capacity may be stretched (flat-out) to just over 80 MW. On the other hand, economic growth and increased access has meant that during peak times (especially in the winter months) demand can be as high as 120 MW. So far, the deficit is offset by supply imported from Eskom (South African power utility), and more recently from EDM (Mozambique power utility). Lesotho is a member of the Southern Africa Power Pool (SAPP), which interconnects the power utilities of the region. However, regional shortages of electricity mean that this supply cannot be guaranteed. The problem is further compounded by the country's dilapidated electricity distribution network infrastructure.

3.2. Connections and access rate

Fig. 3 shows the historical development of grid connections and electricity demand since LEC started its operation in 1969. As of June 2011, 22% of Lesotho households had access to electricity, primarily concentrated in the urban and growth centres where infrastructure services are relatively well developed in terms of transmission and distribution [15a]. Less than 6% of the area serviced by grid is defined as rural. It should be noted that as of June 2011, the electrical system's maximum demand for the entire country is around 120 MW, that is, 45 MW more than the local generation capacity. Besides an exponential increase in grid connections, also shown in the graph (Fig. 3), is a steady increase in demand for power over the last four decades from 15.8 MW in 1971 to 120 MW in 2010. The historical trend in grid connections, N_C, is given by:

$$N_C = 2.38 \times 10^{-86} \times \exp\left[\frac{t}{9.64}\right], \quad (1)$$

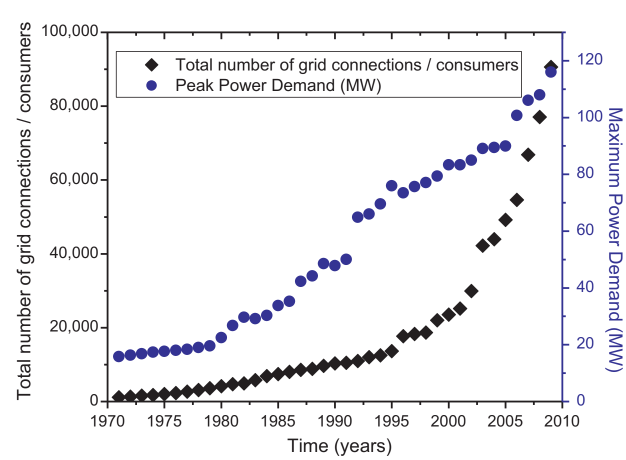

Fig. 3. Electricity connections and power demand: 1970–2010.

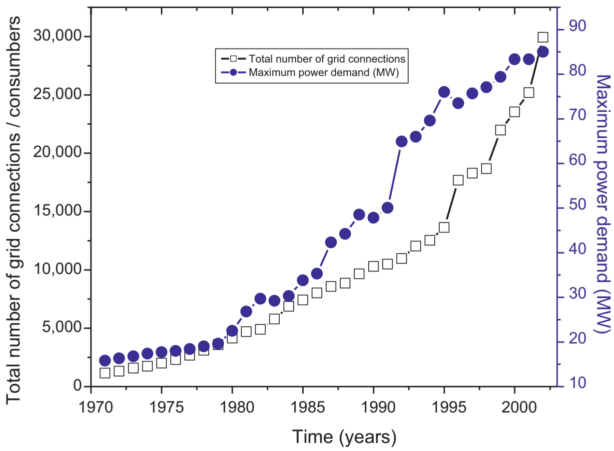

Fig. 4. Pre-reform electricity connections and power demand.

where t is time elapsed in years. The power demand, P_d, is given by:

$$P_d = 2.71 \times t - 5347, \tag{2}$$

The data is taken from press releases, company websites, public reports [15b,16] and extrapolated from Lesotho Electricity Authority (LEA) and LEC projections. The load growth may be attributed to increased mining activities, construction of large dams, and development of the textile industrial base. It should be noted that for the years 1992 (due to construction of LHDA Katse and Mohale dams) and 2006 (mining activities), there were sharp increases in power demand. The current growth rate is estimated at 2.70 MW/annum. At the present growth rate, power demand is expected to reach 138 MW (peak) in 2015 and 160 MW (peak) in 2020, which is more than twice the current generation capacity.

In 2005, 11% of the population had access to electricity, compared to just 5% in 2000. This means by 2000, only 22,800 of the estimated 380,000 Lesotho households had been connected to the grid since the LEC started operations in 1969. In 2003, a total of 12,271 new connections were made – a 159% increase from 4738 made in 2002.

Since 2005, grid connection grew by 84.5%, from 49,184 to 90,581. In 2008, a total of 12,215 new electricity connections (11,612 domestic connections or 95%, 601 general purpose (small business) and 2 industrial connections) were made, this is a 124% increase from the 5445 connections made in 2007. As shown in Figs. 4 and 5, prior to 2001, the average annual increase in the number of connections was around 700 whereas the figure increased by more than a factor of 10–8000 connections per year thereafter. It should be noted that an average of 10,000 new connections were made between 2008 and 2010. The exponential increase was, to a large extent, a result of government restructuring of the electricity industry sector in 2001 and Government subsidized rural electrification schemes.

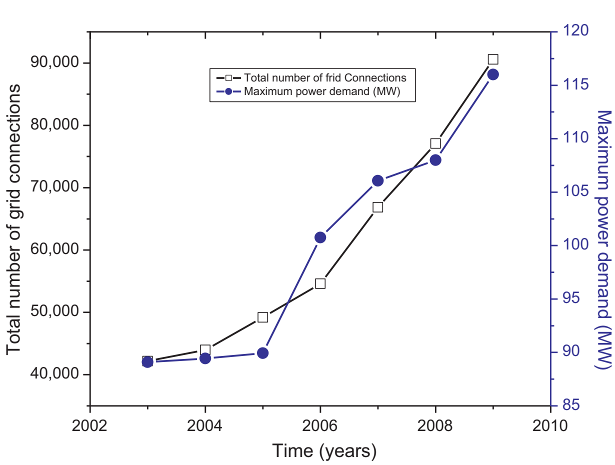

Fig. 5. Post-reform electricity connections and power demand.

3.3. Power sector reforms overview and policy briefs

In a major effort to reform the company and improve efficiency, an Interim Management Task Force (IMTF) was appointed in February 2001 to manage the LEC, to improve operational efficiency and financial performance, with expectations that the utility will be privatised in the near future. The reforms were meant to address the problems of inefficiency and lack of financial resources in the sector [17,18]. The restructuring entailed commercialisation of the state-owned utility, the establishment of rural electrification structures, making the 'Muela hydropower facility prices competitive, and the creation of the policymaking and regulatory authority, LEA, which has been a member of the Regional Electricity Regulators' Association of Southern Africa (RERA) since 2005. A combined regulatory body, Lesotho Electricity and Water Authority (LEWA) for water and electricity regulation was also established in 2008.

As part of its drive to increase rural access to electricity and expand the use of PV in rural electrification, the Government established the Rural Electrification Unit (REU) within the Department of Energy (DOE). The goal was to use subsidy to turn rural electrification into an attractive business opportunity. This newly established unit is faced with the challenge of capacity. The Local Government structures are not ready to take the responsibility of being a distribution utility. This kind of service is not even included in schedule of services that can be rendered by the Local Government. DOE, through Lesotho Meteorological Services and financial assistance from UNDP Lesotho has engaged a consultant to develop the country's Renewable Energy Policy which is expected to be ready during the first quarter of 2012.

3.4. Grid electrification challenges: power shortages and constraints

It is evident that the future demands for electrical energy will continue to increase as the country further develops. As such if additional generation capacity is not created, the country may face serious power shortages in the near future. Since 1998, growth in peak demand for electricity has exceeded transmission growth by almost 5% every year. Unfortunately, there have not been corresponding investments in generation and transmission infrastructure, resulting in cumulative deficit. While promoting demand management to cope with the immediate shortfall, the Government of Lesotho is currently exploring long term solutions to increase supply. These include expansion of MHP capacity, developing new hydropower stations, as well as examining the feasibility of building wind farm(s), supporting the use of off-grid renewable energy solutions such as solar and wind power, and re-commissioning existing mini hydro-power stations, of which there are four. The persistence of drought, which led to the original decision to shut down these mini-hydro plants, may still be a problem.

With no medium-term relief available to ease the power shortages, the situation is expected to continue beyond 2015. Currently, Lesotho's internal generation satisfies only 62.5% of its demand. Present arrangement with Eskom and EDM allows the LEC to cover the shortfall through purchases of electricity from the two organisations. However, such dependence on external sources makes Lesotho insecure in terms of supply. As such, it is important for the country to pursue diversification of its own power generation sources. To avoid a worsening situation in the years ahead,

appropriate policies must be put in place and the country will have to exploit its huge natural renewable resources. One of the major thrusts of the government is to encourage energy resource diversification to achieve a wider energy supply mix, which will ensure greater energy security for the nation.

3.5. Impact of the electricity crisis

While the cost of electricity in Lesotho is still among the lowest, rapid industrialization and a mass electrification program led to demand for power outstripping supply in early 2008. During the winter of 2008, Lesotho suffered unprecedented power outages due to power crisis in South Africa. This forced LEC to introduce load-shedding, rationing electricity to parts of the country, as there were limits to the amount of imports available, in order to provide for the equitable supply of electricity. Although LEC tried to manage the electricity crisis primarily through an extensive media information campaign advising when power shedding would occur and ways to conserve energy, the situation still resulted in major economic and personal misery. Those hardest hit were entrepreneurs and small businesses, as well as the health sector where provision of health services to patients was severely compromised, and thousands of dollars' worth of medicine were destroyed due to lack of proper storage. Although no official report has been published on the impacts of the 2008 load-shedding, interviews with the Lesotho Chamber of Commerce and Industry, following a survey of members, indicated that the blackouts cost the Lesotho economy about $5 million directly [19]. There were various media reports covering the extent of the damage to businesses and households – including damaged computers, traffic congestion, and wasted perishables [20], mainly because the information about when and where blackouts were to occur was generally incorrect. Other media reports estimated that $25,000 was spent on purchase of generators to mitigate the impacts of the power cuts.

3.6. Grid electrification outlook

In the past, a major barrier to customers signing up for connections was the LEC's rigid policy on a "connection fee" whereby the full cost of connection, usually more than US$500, was required upfront, which proved prohibitive for many potential customers. The connection fees included the cost of material and labour. Resources from the Lesotho Utility Reform Project loan have enabled the LEC to reduce the up-front charge to US$75 with the balance to be collected with energy charges for a period of up to seven years. The management contractor holds the view that further reductions in the upfront connection charge will be the most effective means of improving the take-up rate, thereby facilitating the expansion and penetration of electricity service. Such a measure is only possible, however, if an enduring mechanism is found to bridge the financial gap implied by new connections.

The Vision 2020 energy target is to have at least 35% of the population connected to electricity by 2015 (up from the current 20%), 40% by 2020 and to reduce the rate of wood use in national energy consumption [12]. If the current rate of electrification remains nearly constant, it is expected that around 144,533 connections will be achieved by 2015, and around 242,792 by 2020. While attainable, the projected growth will require strong political and financial commitment as well as immediate action by governments and stakeholders. Large capital investments will be needed to modernize and expand energy infrastructure, particularly in the power generation and distribution sectors. The 2007 National Electrification Master Plan (NEMP) estimated that around US$410 million is required to meet government's target of 40% electrification level by 2020 [21]. The Government budget alone cannot match this requirement. Other sources of financing will have to be identified. LEA has already established a fund whose main objective is to subsidize costs for electricity service connection for domestic consumers.

The grid extension is more expensive in rural areas because of low population densities, low capacity utilization rates, and high requirements for accompanying infrastructure development, such as road building. The long distances mean greater electricity losses and more expensive customer support and equipment maintenance. Extending the lines to rural areas therefore would only increase the costs of the overall distributed electricity. The current average cost of electrification in rural areas is estimated to range between US$1500 and US$1800 per connection within 3.5 km of existing distribution line, rising to more than US$2250 in difficult terrains and beyond 3.5 km of the existing distribution line. Thus rural electrification projects have often required Government subsidies to make them financially affordable for customers.

LEC operates within a defined *Service Territory* which comprises areas within 3.5 km radius of the existing distribution network. This territory constitutes a geographical area where grid electrification is considered financially viable, the distribution networks are fully established and income level of households and population densities are relatively high compared to remote rural areas (typically US$350). These characteristics guarantee better return on investment. LEC only undertakes connections that fall outside its remit upon provision of subsidy from the National Rural Electrification Fund. Otherwise, rural electrification programmes are currently undertaken by the Rural Electrification Unit (REU), which falls under the Department of Energy and is funded by the National Rural Electrification Fund.

4. GEF rural PV electrification project

4.1. Overview of Lesotho solar PV electrification project

DOE through REU, in cooperation with UNDP, is implementing the Lesotho Renewable Energy-Based Rural Electrification (LREBRE) project in the three districts of Mokhotlong, Thaba Tseka and Qacha's Nek, shown in Fig. 6. REU launched the Lesotho Renewable Energy-Based Rural Electrification (LREBRE) Project [22].

The project's main objective is to reduce Lesotho's energy-related CO_2 emissions by promoting renewable energy technologies (RETS) – in particular stand-alone solar PV systems for households – as an affordable substitute for fossil fuel-based energy sources in rural areas with low load density which are remote from the national electricity grid. The activities proposed in the project – ranging from awareness-building and training for industry actors to support for the actual instalment of RET systems – were designed to remove critical barriers to the wide-scale utilization of RETs in rural areas and create the enabling environment for the long-term growth and sustainability of a market-based RET in Lesotho. The project is focused on MDG7 "*Ensuring environmental sustainability*" and supports the broader objectives of MDG1 "*poverty reduction*" through household income, health, education, gender, and the environment.

This project is jointly funded by the Global Environment Facility, GEF (through the UNDP) and the Government of Lesotho (GOL). GEF provided part of funding of around US$2.5 million, while to date (2011) GOL has provided US$4.2 million: US$725,000 (in 2008), US$725,000 (in 2009), US$2 millions (in 2010) and US$725,000 (in 2011). The duration of the project is 5 years (2007–2012) during which time 5000 lighting systems are to be installed in rural homes and public institutions.

Geographical locations, in particular where the cost of main grid service would be prohibitively high and could not be made available in the foreseeable future, as well as future expansion plans of main

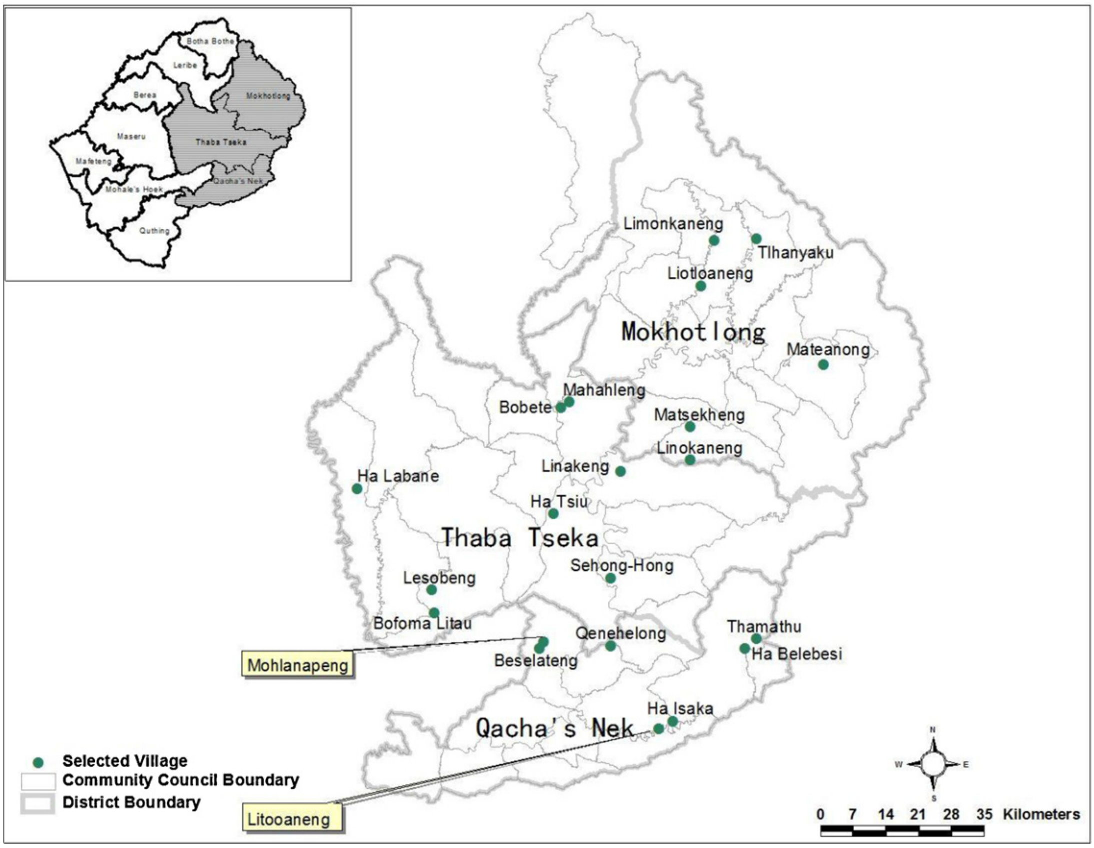

Fig. 6. GEF/LREBRE current Solar PV Project Areas as of March, 2011.

grid, and the likelihood of such expansion, are all being considered as criteria for selecting the potential villages for electrification by the project. In addition, the socioeconomic position of rural households and their perception of the costs of PV electricity are also being considered as determinants for the provision of greater penetration of PV panels as energy source at household level. These are also the villages in the focus of the Lesotho Government's rural development programme.

The project provides PV Solar Home Systems (SHS) that are mainly used for lighting by rural dwellers. Each SHS consists of a 65 W, pole/roof-mounted PV panel, 105 Ah deep discharge battery, a battery control unit, 6 A regulator, 150 W DC/AC inverter, 3-CFL type lamps (3×18 W). Currently, the upfront price of a 65 W PV system is set at US$1864.37 (installation and a year of maintenance) for households, with the Lesotho Government paying for US$1567.72 (84% of the capital cost) as a direct subsidy and the remainder of US$296.62 (16% of the capital cost) repaid by end-users as a soft loan over a seven year period. A monthly fee of US$3.50, set aside for amortising the system, is paid to the installer by each individual consumer. This fee is much less than average monthly expense of around US$10 incurred per household for the purchase of kerosene and candles for light. The current project subsidization structure and soft loan amount for a PV system (US$296.62 or 16% of the capital cost of a system) is based on parity with the current Lesotho connection fee policy for households to the national grid, set at US$296.62.

4.2. Results and impacts

The project, now it is in fourth year of implementation in a five year project lifespan, has made important progress in meeting many of its targeted objectives and removed a wide range of institutional, cultural and informational barriers to the adoption of RETs in Lesotho. Demand for RETs in Lesotho and general awareness of the benefits of RETS among both policy-makers and the general public has increased exponentially because of project activities. As of March 2011, the project has directly installed 1537 PV systems, with a cumulative power of 100 kW, in the targeted districts. Around the same period, an estimated 500 PV systems have been installed indirectly as a result of the project influence. However, there has also been a decline in direct sales of PV systems through cash purchases as many rural customers wait for their turn in the government subsidy program [23]. With the current 2011 allocation, about 300 installations can be realised if the same design and subsidy is deployed, which implies that more than US$5 million will be required if 5000 systems are to be realised by the end of the project.

In its endeavor to support and assist the development of the solar industry in Lesotho, the reactivation and support of Lesotho Solar Energy Society (LESES) is certainly a major project outcome. The benefits are not restricted to the users, but also extended to those participating in sales and, more particularly installation activities. It is estimated that by late 2010, more than 100 PV installers and/or dealers were registered with LESES, which represents a significant increase from the pre-LREBRE period when only a handful of small companies and individuals were engaged in PV system installations and/or sales. More than 80% of the solar dealers in Lesotho are now members of LESES. One of the most significant policy impacts has been the project's indirect influence on the successful introduction of renewable energy policy targets. The project has, in 2008, ensured that renewable energy technologies were featured in the National Rural Electrification Master Plan, and that local PV installers are aware and trained on the use of the Lesotho PV Code of Practice. There has been access to imported solar components. Community participation and the establishment of cooperatives are being encouraged.

To strengthen and support the public and private sector working in the renewable energy sector and to provide better quality of service to the rural areas in 2008–2010, the project organised technical training to equip community representatives with basic skills in PV systems operation, troubleshooting, basic repairs and maintenance. Along with these courses, business training for solar dealers to strengthen their entrepreneurial capacity was offered. The technical capacity of key industry stakeholders has been significantly improved as a result of project activities. A series of training programmes and workshops designed to develop a critical mass of locally trained personnel in PV business management, PV code of practice and systems installation and maintenance are being conducted. Solar PV installers' certification programme has also been launched in collaboration with LESES.

Awareness raising programmes were developed, including a series of field visits, awareness campaigns and product demonstrations which were held in the first year in the three target districts. Using information leaflets, promotional materials, radio programmes, workshops, exhibitions and meetings, the project sensitized the general public, rural communities and decision makers on the potential role of renewable energies in meeting basic energy needs in rural areas.

REU also intends to design and lobby for practical mechanisms that would allow permanent reductions in value added tax and excise duties on SHS components. This is expected to reduce the cost of a roof-top solar panel installation by 15–20%. In addition, the project hopes to lobby for introduction of '*net metering*' options to encourage take-up of such systems – where small-scale generators get paid for their net electricity production, over and above their domestic needs. It is hoped that the project will benefit the private sector, as they will be the main vehicle to roll out the products and services.

4.3. Benefits of PV systems

In order to obtain information from the households on their experience since the installation of the solar panels, the village chiefs/headmen or their representatives were interviewed. The selection was based on a stratified random sampling method where 9 chiefs/headmen were randomly selected out of the total number of 21 in Thaba-Tseka, Mokhotlong and Qacha's Nek districts. The interview was aimed at giving the village representatives the opportunity to discuss their communities' experiences with the PV project, i.e. from planning to implementation and operation. The interviews also provided an avenue to ask community representatives whether their communities had any basic knowledge of how to operate the facility and repair broken facilities. This approach enabled us to discuss with the beneficiaries the problems they encountered and their impression of the implementation of the project. The approach also enabled us to determine if the end users were adequately consulted during the planning and implementation stages of the project.

PV systems in these villages have offered tremendous benefits. Preliminary feedback and monitoring reports indicate an improved standard of living for the villages, decline in stock theft (which has become endemic in much of Lesotho) and housebreaking, and that the PV based electricity is an appropriate technology suitable for dissemination in the rural areas of Lesotho. The households powered by the system are now spending less on kerosene and candles. Improvement of children's education, entertainment and awareness through television/radio are also stated as prominent effects of PV electrification in these villages. Since electric lighting is up to 200 times brighter than kerosene lamps, reading and recreation at night are carried out under lighting with sufficient luminous intensity. Prayer meetings and ceremonies can now be held in the village at night without having to worry about kerosene or hiring diesel generator sets. The patronage and income of commercial activities (bars and provision stores) enjoying the power supply from the PV system have been enhanced. Schools have reported increased enrolment and an enhanced culture of learning and teaching with the use of modern technologies, and qualified teachers are attracted. Access to equipments like overhead projectors, television sets and VCRs, photocopiers, and computers have enhanced the culture of teaching and learning.

The impact of the systems has stimulated the interest of nearby villages which have placed requests for extension of the facilities to them. Shop owners in rural markets have significant interest in using small solar systems for charging mobile phones, which is stimulating rural economies, enabling grass-roots businesses to emerge, as well as creating jobs and driving forward social change. The use of television and radio in rural facilitates the ability of business advertisers to reach a wider audience.

4.4. Social barrier: poor matching of individual and national development objectives

This project has been based on the assumption that rural communities need alternative energy sources to displace fuel wood. A further assumption is that renewable energy sources are suitable because they are cleaner and help protect the environment. The energy source or technology must contribute to basic energy needs – lighting, space heating, water heating, cooking and productive use. Renewable electricity that does not deliver services like cooking or productive use is limited in its contribution to sustainable livelihoods. PV systems deliver electrical energy but fall short of in meeting the major energy needs of rural communities. The general response to the GEF-PV project has been that PV power cannot provide energy for cooking hence the basic needs are still unmet. Also, the need for new economic activities has not been taken as a major criterion for energy planning in rural areas as far as renewable energy is concerned. The global objective has been to meet the current household activities with renewable energy technologies thereby creating a technology market without empowering the market to pay.

4.5. Problems likely to hinder the growth of solar energy

The rise in awareness of about PV systems has brought with it an undesirable complication to the infant PV market, in the form of increased number of informal and unqualified PV operators. While the informal operators have added volume and dynamics to the promotion of solar energy, they are also posing serious challenges in terms of quality, both of the products and of the workmanship. This group uses mainly the amorphous type PV panels with a much lower efficiency compared to the polycrystalline modules that are commonly used and recommended by the LREBRE project [24]. Another major problem with the informal operators has been that often people who have no expertise or training in PV systems carry out the installations, and as a result such systems experience breakdowns within a short time of installation. The proliferation of this group is having some impact on the PV industry on two different fronts. Firstly, they are competing against certified companies, which are subjected to stringent quality control under the LESES and LREBRE project. Secondly, the PV industry is still young, and this could damage the industry's reputation and slow the public's adoption of renewable energy technologies. Poor quality system or workmanship normally leads to continuous breakdown of the systems.

One other major barrier that is impacting on the market performance of the PV industry is the increase in theft and vandalism of PV panels and equipment from rooftops [25]. Unfortunately, there is no clear strategy to combat this crime that is impacting negatively

on the solar industry. For large installations, not only does theft discourage the institutions from using solar energy, but also distorts the private sector market for PV panels because stolen items re-enter the market. Ingenious technical designs are being applied to prevent theft, but with little success. It is common to see steel bars shielding the panels or increased heights of the poles raised above the rooftops as a way of deterring potential theft, which may affect the output from the panels due to obstruction of the sunlight.

5. Conclusion and outlook

Inevitably the status of power supply in Lesotho is, and continues to be precarious. Although Lesotho is on track to realise its ambitious but achievable electrification targets for 2015 and 2020, the available generating capacity of the national electricity grid supply system is not sufficient to meet the growing electricity demand. The expansion of MHP is now a matter of urgency. The opportunities available for PV in Lesotho are enormous and a highly positive growth trend is foreseen for PV electricity generation. The PV industry has to continue this growth over the next years in order to maintain this level.

Power stations take many years to construct and commission while PV interventions can usually be completed within days. The case in favour of PV is thus easily made. However, increasing energy access is not simply about supplying lighting. To promote economic development and growth, energy services must also be put to work towards wealth creation – providing power for businesses, and improving healthcare, education and crop production. Many attempts to increase people's access to modern energy services have involved subsidies. PV electrification interventions are found only to take off with government support in the form of a subsidy. However, experience has repeatedly shown that electricity subsidy schemes cannot be sustained over the long term and do not effectively address these issues.

Policies to encourage the dissemination of solar energy systems in the country have been put in place but specific policies and incentives for solar PV are lacking. More promotional and training activities are needed to ensure that PV takes up a reasonable share of the energy supply mix of the country in future.

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